DESCRIPTION

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PIEZOELECTRIC DEVICE

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Technical Field

The present invention relates to piezoelectric devices, and in particular relates to a piezoelectric device having piezoelectric elements using a piezoelectric substrate and a piezoelectric thin film, such as a resonators and a filter.

Background Art

Recently, a chip-size package (CSP) has been developed in that a piezoelectric device, such as a surface-acoustic-wave filter (SAW filter) using a piezoelectric substrate and a bulk-acoustic-wave filter (BAW filter) using a piezoelectric thin film, is miniaturized until an element chip size.

For example, a piezoelectric device 2 shown in Fig. 5 includes a piezoelectric substrate 3 having piezoelectric elements including IDTs (interdigital transducers; interdigital electrodes) 4a and an electrically conductive pattern, such as pads 4b, formed on one principal surface 3a of the piezoelectric substrate 3; a cover 6 covering the one principal surface 3a with a support layer 5 therebetween; and external electrodes 7, which are exposed outside the cover 6. The piezoelectric device 2 is mounted with the face down at a predetermined position of a wiring pattern 1a of a circuit board 1 (see Patent Document 1, for example).

Patent Document 1: Japanese Unexamined Patent Application Publication No. H11-251866 (Fig. 1)

Disclosure of Invention

Problems to be Solved by the Invention

The piezoelectric device 2 disclosed in Patent Document 1

electrically connects the external electrodes 7 to the pads 4b by forming holes on the cover 6 so as to be embedded with the external electrodes 7 by electrolytic plating or evaporation. Accordingly, since the vibratory space around the IDT 4a cannot be sufficiently sealed, it has been necessary to seal the piezoelectric device 2 by covering it with a reinforcing resin 9 with a buffer resin 8 therebetween after mounting the piezoelectric device 2 on the circuit board 1.

In view of such situations, it is an object of the present invention to provide a piezoelectric device capable of improving moisture resistance while being miniaturized, which need not be sealed after being mounted on a circuit board, and a manufacturing method of the piezoelectric device.

Means for Solving the Problems

In order to solve the problems described above, the present invention provides a piezoelectric device constructed as follows.

A piezoelectric device includes: a) an element substrate having a piezoelectric element and an electrically conductive pattern connected to the piezoelectric element, which are formed on a principal surface; b) a supporting layer arranged in the periphery of the piezoelectric element on the principal surface of the element substrate; c) a cover extending so as to form a space inside the external periphery of the element substrate, the space ranging over the entire external periphery of the element substrate, by removing part of elements inside the external periphery of the element substrate viewed from the normal direction of the principal surface of the element substrate after the cover is arranged on the supporting layer; d) an insulating reinforcing material that entirely covers portions of the element substrate adjacent to the cover ranging from the cover to the periphery of the principal surface of the element substrate; and e) an

electrically conductive member electrically connected to the electrically conductive pattern so as to pass through the cover and the reinforcing material.

In the configuration described above, the piezoelectric element opposes the cover with an interval of the supporting layer therebetween and a space is formed around the piezoelectric element, so that the piezoelectric element freely operates. Since the piezoelectric element can be sealed with the reinforcing material, the piezoelectric device is improved in moisture resistance, which need not be sealed with a resin after being mounted on a circuit board.

Preferably, the cover extends to the outside of the supporting layer from its periphery viewed from the normal direction of the principal surface of the element substrate.

In the configuration described above, the cover member larger than that of the supporting layer is arranged on the supporting layer, and by removing the outside of the supporting layer, only the cover member is removed without removing the supporting layer so as to form the cover with the removed cover member. The removing workload can be thereby reduced as small as possible so as to increase the processing speed. Also, the contact area between the cover and the reinforcing material can be increased, improving the sealing ability.

Preferably, the cover or the supporting layer is one of a polyimide resin, a benzocyclobutene resin, and a silicone resin while the reinforcing material is an epoxy resin or a silicone resin.

If a halogen gas is generated during the curing of resins, characteristic deterioration is caused due to the corrosion of the piezoelectric element or the element substrate and the gas adhesion to the surface of the piezoelectric element. By the above-configuration, such a problem can be prevented because of the resins which do not generate the halogen gas.

In order to solve the problems described above, the present

invention also provides a manufacturing method of a piezoelectric device constructed as follows.

A manufacturing method for simultaneously manufacturing a plurality of piezoelectric devices includes the steps of: a) a first step of arranging a cover on a supporting layer while forming a first electrically conductive member penetrating the cover to be connected to an electrically conductive pattern, on an element substrate having a piezoelectric element and the electrically conductive pattern connected to the piezoelectric element, which are formed on a principal surface, and the supporting layer formed around the piezoelectric element; b) a second step of removing portions ranging from the cover to the element substrate at least inside the external periphery of the element substrate by a laser beam so as to form a space inside the external periphery of the element substrate to be one piezoelectric device viewed from the normal direction of the principal surface of the element substrate, the space extending over the entire external periphery of the element substrate; and c) a third step of arranging an insulating reinforcing material on the element substrate and the cover so as to entirely cover portions of the element substrate adjacent to the cover ranging from the cover to the element substrate while forming a second electrically conductive member penetrating the reinforcing material to be connected to the first electrically conductive member.

The piezoelectric element opposes the cover with an interval of the supporting layer therebetween and a space is formed around the piezoelectric element, so that the piezoelectric element freely operates. Since the piezoelectric element can be sealed with the reinforcing material, the piezoelectric device is sufficiently improved in moisture resistance, which need not be covered with a resin after being mounted on a circuit board.

When the cover is removed by laser, if there is no supporting

layer arranged along the boundary between piezoelectric devices, each being one piezoelectric device, only the cover is removed; if the supporting layer exists, it is also removed.

When the external electrodes are provided adjacent to the reinforcing material, in order to route wiring for electrically connecting between the electrically conductive pattern of the element substrate and the external electrodes, through-holes are formed in the cover. By the laser used for forming the through-holes, the cover may also be removed.

Preferably, the wavelength of the laser beam is 355 nm or less.

The laser beam with this wavelength removes resins but does not remove metals. Hence, when an electrically conductive pattern, such as a metallic power feeding line, is formed on the element substrate along the boundary between piezoelectric devices, each being one piezoelectric device, only the cover is removed while the metallic power feeding line is left so as to be used for power feeding during electrolytic plating and pyroelectric grounding of the element substrate after removing the cover.

Preferably, the method further includes a Step, prepared between the first and second steps, of removing the electrically conductive pattern formed on the principal surface of the element substrate along the boundary between the piezoelectric devices, each device being one piezoelectric device.

In this case, there is no electrically conductive pattern between the element substrate and the reinforcing material, so that the device can be improved in moisture resistance.

The electrically conductive pattern formed along the boundary between piezoelectric devices can be used for the power feeding line of the electrolytic plating; however it cannot be used after the pattern is removed, so that it is difficult to form the external electrode by the electrolytic plating. In this case, the pattern is

formed by electroless plating. Alternatively, before arranging the reinforcing material, a metallic column may be formed on the cover as a second electrically conductive member so as to electrically connect to the first electrically conductive member, so that the metallic column may be exposed from the reinforcing material after the reinforcing material is arranged.

Preferably, the third step includes curing the reinforcing material arranged on the element substrate and the cover in a reduced-pressure atmosphere.

Even if the curing gas generated during the curing of the reinforcing material contains an adverse-effective ingredient, such as halogen gas, causing characteristic deterioration, the ingredient can be prevented from entering the sealed space enclosing the piezoelectric elements can be prevented, thereby preventing the characteristic deterioration due to the adverse-effective ingredient contained in the curing gas.

Advantages

A piezoelectric device according to the present invention can be improved in moisture resistance while being miniaturized, which need not be sealed after being mounted on a circuit board. According to a manufacturing method of a piezoelectric device of the present invention, the device can be improved in moisture resistance while being miniaturized, so that a surface acoustic wave device can be manufactured, which need not be sealed after being mounted on a circuit board.

Brief Description of the Drawings

Fig. 1 is a sectional view of a surface-acoustic-wave filter (first embodiment).

Fig. 2 is a plan view of the surface-acoustic-wave filter (first

embodiment).

Fig. 3 is an exemplary view illustrating a manufacturing process of the surface-acoustic-wave filter (first embodiment).

Fig. 4 is an exemplary view illustrating a manufacturing process of the surface-acoustic-wave filter (second embodiment).

Fig. 5 is a sectional view of a surface-acoustic-wave filter (conventional example).

Reference Numerals

10, 10a: surface-acoustic-wave filter (piezoelectric device)

12: piezoelectric substrate (element substrate)

14: top surface (principal surface)

15: bottom surface

20: metallic film

22: IDT (piezoelectric device)

24: pad (electrically conductive pattern)

30: supporting layer

34: peripheral face

50: cover

70: reinforcing material

80: external electrode

Best Mode for Carrying Out the Invention

Embodiments of the present invention will be described below with reference Figs. 1 to 4.

As shown in the sectional view of Fig. 1, a surface-acoustic-wave filter 10 includes a piezoelectric substrate 12 having piezoelectric elements including IDTs 22 and an electrically conductive pattern including pads 24 formed of metallic films 20 on one principal upper surface 14 of the piezoelectric substrate 12. On the upper surface 14, a cover 50 is arranged with the interval of a supporting layer 30

therebetween so as to form a vibratory space 26 around the IDTs 22. The supporting layer 30 is formed around the IDTs 24, and surface acoustic waves freely propagate through the supporting layer 30 adjacent to the vibratory space 26 of the piezoelectric substrate 12. Furthermore, an insulating reinforcing material 70 entirely covers the portion from the cover 50 to the periphery of the upper surface 14. From the reinforcing material 70, external electrodes 80 are exposed, so that the surface-acoustic-wave filter 10 can be mounted on a circuit board of electric instruments. On the other principal surface 15 of the piezoelectric substrate 12 (bottom side in the drawing), a protection resin 16 is arranged.

The cover 50 extends until the peripheral face 34 of the supporting layer 30 so as to cover the supporting layer 30, and it may also extend toward the outside of the peripheral face 34. As will be described in detail, through-holes are formed in the cover 50 and the reinforcing material 70 so that electrical wirings are inserted therethrough so as to connect between the pads 24 and the external electrodes 80.

The reinforcing material 70 extends along the external periphery of the upper surface 14 of the piezoelectric substrate 12 and over the entire periphery thereof so as to seal off the upper surface 14 of the piezoelectric substrate 12. The vibratory space 26 is thereby sealed closely and shielded from the surroundings.

A plurality of the surface-acoustic-wave filters 10 can be simultaneously manufactured, and Fig. 2 shows the two surface-acoustic-wave filters 10 with a boarder line during manufacturing.

As shown in the plan view of Fig. 2, four external electrodes 80a, 80b, 80c, and 80d are provided as the external electrodes 80. The external electrodes 80a and 80d are ground terminals; the external electrode 80b is an input terminal; and the external electrode 80c is an output terminal.

On the wafer top surface of the piezoelectric substrate 12, a metallic film pattern is formed as schematically shown by dash-dot lines of Fig. 2. In addition, the metallic film pattern is not shown in the right surface-acoustic-wave filter 10 of Fig. 2.

That is, within the surface-acoustic-wave filter 10, four IDTs 22a, 22b, 22c, and 22d are formed as the IDT 22; and five pads 24a, 24b, 24c, 24d, and 24x are formed as the pads 24. Also, wirings are provided so as to connect between the IDTs 22a, 22b, 22c, and 22d and the pads 24a, 24b, 24c, 24d, and 24x. On the other hand, on the border between the surface-acoustic-wave filters 10 adjacent to each other, an electrically conductive line 21 is formed. Furthermore, short lines 25a, 25b, 25c, and 25d are formed for connecting the electrically conductive line 21 to the wirings within the surface-acoustic-wave filter 10. On both sides of the IDT 22a, on the IDT 22b opposite to the TDT 22c, on the IDT 22d opposite to the IDT 22c, reflectors may be provided. The metallic pattern other than the IDTs and the reflectors is not necessarily surrounded by the supporting layer. For example, part of the wirings connecting the pads 24a, 24b, 24c, 24d, and 24x to the IDTs may be exposed from the supporting layer 30.

The cover 50 arranged on the supporting layer 30 is provided with below-mentioned through-holes (via holes) formed at positions corresponding to those of the pads 24a, 24b, 24c, 24d, and 24x. On the top surface of the cover 50, a ground wiring 60 is formed as shown by a double-dotted chain line in the right surface-acoustic-wave filter 10 of Fig. 2. In addition, in the left surface-acoustic-wave filter 10 of Fig. 2, the ground wiring 60 is not shown. Both ends 60a and 60b of the ground wiring 60 are electrically connected to the pads 24a and 24d via the via holes penetrating the cover 50 and the supporting layer 30, respectively. An intermediate point 60x of the ground wiring 60 is electrically connected to the pad 24x connected to

the IDT 24x via the via holes penetrating the cover 50 and the supporting layer 30. The ground wiring 60 is three-dimensionally intersected with a hot wiring connecting the IDT 22a to the IDTs 22b and 22d with the insulating supporting layer 30 and the cover 50 therebetween.

As shown in a dotted line of the right surface-acoustic-wave filter 10 of Fig. 2, the reinforcing material 70 is provided with rectangular holes 72a, 72b, 72c, and 72d formed thereon, and the external electrodes 80a, 80b, 80c, and 80d are electrically connected to the pads 24a, 24b, 24c, and 24d via the holes 72a, 72b, 72c, and 72d, respectively. In addition, in the left surface-acoustic-wave filter 10 of Fig. 2, the rectangular holes of the reinforcing material 70 are not shown.

Next, the manufacturing method of the surface-acoustic-wave filter 10 will be described with reference to Fig. 3.

As shown in Fig. 3(a), on the wafer top surface 14 of the piezoelectric substrate 12, a metallic film 20 is formed. For example, on a LiTaO substrate with a thickness of 0.3 mm and a diameter of 100 mm, parts of the IDTs 22, the pads 24, and the electrically conductive line 21 (see Fig. 2) are formed with an Al film with a thickness of 100 nm by a deposition lift-off technology. The line width of the electrically conductive line 21 is 20 μm. Furthermore, for serving as a power feeding film during subsequent plating, parts of the pads 24 and the electrically conductive line 21 (see Fig. 2) are formed with a thickness of 10 nm and Al with a thickness of 1 μm by a lift-off technology.

Then, as shown in Fig. 3(b), on the wafer top surface 14 of the piezoelectric substrate 12, the supporting layer 30 is formed. The supporting layer 30 is provided with openings formed in portions corresponding to those of the IDT 22 and the pad 24. A space is formed between the surface-acoustic-wave filters 10 adjacent to each

other, and the opening is also formed on the electrically conductive line 21 (see Fig. 2). For example, the wafer top surface 14 of the piezoelectric substrate 12 is coated with a negative-type photosensitive polyimide having a thickness of 20 μm, and it is dried, exposed, post-exposure baked (PEB), and developed so as to form the supporting layer 30 in a pattern having openings formed in portions between the surface-acoustic-wave filters 10 and corresponding to those of the IDT 22 and the pad 24. At this time, by using a gray-tone photo-mask, a forward-tapered inclined surface 32 is formed in the opening of the pad 24, facilitating forming a wiring 40 in the subsequent process.

Then, as shown in Fig. 3(c), a wiring 40 is formed so as to extend from the pad 24 to a pad portion (a line width of 30 μm) of the top surface of the supporting layer 30. The wiring 40 is made of a Cu film with a thickness of 3 μm formed on a Ti film with a thickness of 10 nm, in view of subsequent plating. Simultaneously, the short lines 25a to 25d (see Fig. 2) are also formed on the upper surface of the supporting layer 30 for use as a plating line (the line width: 30 μm, the film thickness: 3 μm) so as to connect between the pad portion (a line width of 30 μm) of the top surface of the supporting layer 30 and the electrically conductive line 21 (see Fig. 2). In addition, if Al is adopted instead of Cu, although it is advantageous to reduce the damage during subsequent laser processing, it is required for a syndicate processing as a preliminary treatment of the plating, increasing manufacturing cost.

Then, as shown in Fig. 3(d), the cover 50 is formed. For example, a sheet made of a polyimide film with a thickness of 15 μm to 30 μm coated with a polyimide adhesive is bonded on the entire wafer surface by a roll laminating method, and is cured at 200°C.

Next, as shown in Fig. 3(e), through-holes (via holes) 52 are formed in the cover 50 while by removing the portion of the cover 50

that protrudes off the peripheral face 34 of the supporting layer 30, a groove 54 is formed in the boundary between the surface-acoustic-wave filters 10 adjacent to each other. For example, by using THG (third harmonic generation) laser, a laser processing residue is removed by O_2 ashing after the via holes 52 with a diameter of 10 μm and the groove 54 are formed on the cover 50.

When the THG laser (wavelength: 355 nm) is used, since the laser-light absorption rate of the polyimide film of the cover 50 is 99% and that of Al of the electrically conductive line 21 and the short lines 25a to 25d is about 10%, when the groove 54 is formed by removing the protruding portion of the cover 50, the electrically conductive line 21 formed on the wafer top surface 14 below the portion cannot be removed by the laser. Even when SHG (second harmonic generation) laser (wavelength: 532 nm) or CO_2 laser (wavelength: 10.6 μm) is used, as long as laser processing conditions, such as thickening the electrically conductive line 21, are appropriately selected, the groove 54 can be formed between the surface-acoustic-wave filters 10 adjacent to each other after one time cutting.

Since the supporting layers 30 of the surface-acoustic-wave filters 10 adjacent to each other have intervals due to the peripheral face 34, only the cover 50 can be removed by the laser in a short time. At this time, for having the same energy density (having an equivalent processing speed and processed shape) when the laser beam diameter is enlarged, large output power is required, so that the processing speed must be increased by reducing the processing width as small as possible so as to increase the energy density. That is, it is preferable that the cover 50 after removal extend outside the peripheral face 34 of the supporting layer 30. Also, the contact area between the cover and the reinforcing material can be increased, improving sealing ability.

Then, as shown in Fig. 3(f), the via holes 52 are embedded with a

conductive material. For example, the via holes 52 are embedded by Cu electrolytic plating using the electrically conductive line 21 as a power feeding film.

Then, as shown in Fig. 3(g), on the cover 50, the ground wiring 60 and a hot wiring 65 are formed for connecting between the via holes 52 and the external electrodes 80. For example, the ground wiring 60 and the hot wiring 65 are formed by the lift-off technology. At this time, in view of the easiness of the subsequent plating, Ti with a thickness of 100 nm, Al with a thickness of 1 μm, and Cu with a thickness of 100 nm are formed in that order.

Next, as shown in Fig. 3(h), after the wafer top surface 14 of the piezoelectric substrate 12, the supporting layer 30, and the cover 50 are coated with the reinforcing material 70, through-holes 72 are formed in the cured reinforcing material 70 so as to expose the ground wiring 60 and the hot wiring 65 as shown in Fig. 3(i). For example, an epoxy resin, a silicone resin, a low-temperature glass fritter, a polyimide resin, or an acrylic acid ester resin is applied as the reinforcing material 70 so as to have a thickness on the cover 50 of 30 μm and form the through-holes 72 with a diameter of 100 μm. The through-holes 72 are formed by lithography when a photosensitive resin is used, and are formed by laser when a non-photosensitive resin is used.

If a halogen gas is generated during the curing of the reinforcing material 70, characteristic deterioration is caused due to the corrosion of the IDT 22 and the piezoelectric substrate 12 and the gas adhesion to the surfaces of elements. It is preferable that a polyimide resin, a benzocyclobutene resin, or a silicone resin be used for the cover 50 and the supporting layer 30, and an epoxy resin or a silicone resin be used for the reinforcing material 70 because the halogen gas does not generate. Even in a resin generating the halogen gas, when the reinforcing material 70 is cured in a reduced-pressure

atmosphere, the halogen gas can be prevented from entering the vibratory space 26, into which the IDT 22 is sealed, preventing characteristic deterioration.

Then, as shown in Fig. 3(j), the external electrodes 80 are formed, which are connected to the ground wiring 60 and the hot wiring 65 via the through-holes 72 while a protection resin 16 is formed on the bottom surface 15 of the piezoelectric substrate 12.

Specifically, as a sub-film of the external electrode 80, Ni with a thickness of 300 nm and Au with a thickness of 100 nm are sequentially formed on portions of the ground wiring 60 and the hot wiring 65 exposed from the through-holes 72 by electrolytic plating. Instead of forming the sub-film, the external electrodes 80 themselves may also be electro-plated with Ni and Au by embedding the through-holes 72 with Cu electrolytic plating. Then, after the entire wafer bottom surface of the piezoelectric substrate 12 is coated with an epoxy resin with a thickness of 10 μm, beaded external terminals are formed by printing the solder for external electrodes on portions of the through-holes 72 and by reflow-soldering thereon.

Finally, by dicing the wafer of the piezoelectric substrate 12 at the boundary between the surface-acoustic-wave filters 10 adjacent to each other, the piezoelectric substrate 12 is divided into each piece of the surface-acoustic-wave filter 10. At this time, by cutting the reinforcing material 70, the supporting layer 30 and the cover 50 are prevented from being exposed due to the dicing. However, the cut surfaces of the short lines 25a to 25d (see Fig. 2) are exposed from side faces of the divided surface-acoustic-wave filter 10.

When the surface-acoustic-wave filter 10 is manufactured as described above, the alignment joining process is eliminated and the cover 50 is made by inexpensive roll lamination, so that manufacturing cost can be reduced. By using the THG laser, the via holes 52 with a diameter of 10 μm can be formed so as to miniaturize the elements.

Since a photosensitive resin is not used, the degree of freedom of selecting materials is increased for the cover 50 and the reinforcing material 70. The cover 50 and the wirings are covered with the reinforcing material 70 so as not to expose outside, securing reliability. Since the wiring is formed by plating, the non-defective rate in via conduction is excellent. By combing plating with soldering, the strength of the external electrode 80 is increased. For the reinforcing material 70 and the protection resin 16, the strength against a mounting impact i can be secured. Since the supporting layer 30, the cover 50, and the reinforcing material 70 are resins and owing to their buffer effects, defects, such as wire breaking, are difficult to be caused by the mounting impact and a thermal impact.

Next, a surface-acoustic-wave filter 10a according to a second embodiment will be described with reference to Fig. 4.

According to the second embodiment, part of the manufacturing process is different from the first embodiment, so that cut surfaces of the short lines 25a to 25d (see Fig. 2) are not exposed from the side faces of the surface-acoustic-wave filter 10a. Points different from the first embodiment will be mainly described below.

As shown in Figs. 4(a) to 4(d), after the metallic film 20 is formed on the wafer top surface 14 of the piezoelectric substrate 12, the supporting layer 30 is formed in the same way as in the first embodiment. Then, after the wiring 40 extending from the pads 24 to the top surface of the supporting layer 30 is formed, the wiring 40 is covered with the cover 50.

Then, as shown in Fig. 4(e), the through-holes (via holes) 52 are formed in the cover 50, and the via holes 52 are embedded with a conductive material. For example, after forming the via holes 52 with a diameter of 10 μm on the cover 50 using the THG laser, a laser processing residue is removed by O_2 ashing. Then, the via holes 52 are

embedded by Cu electrolytic plating using the electrically conductive line 21 (see Fig. 2) as a power feeding film.

Then, as shown in Fig. 4(f), the ground wiring 60 and the hot wiring 65 are formed on the cover for connecting the via holes 52 to the external electrodes 80. For example, the ground wiring 60 and the hot wiring 65 are formed by a lift-off technology. At this time, in view of subsequent plating, Ti with a thickness of 100 nm, Al with a thickness of 1 μm, and Cu with a thickness of 100 nm are sequentially formed.

Then, as shown in Fig. 4(g), the groove 54 is formed on the cover 50. At this time, the short lines 25a to 25d connecting between the electrically conductive line 21 and the pads 24a to 24d are also removed (see Fig. 2). For example, after the processing using the THG laser, a laser processing residue is removed by O_2 ashing.

Then, as shown in Fig. 4(h), the wafer top surface 14 is coated with the reinforcing material 70 so as to cover the supporting layer 30 and the cover 50 with the reinforcing material 70, and then, as shown in Fig. 4(i), the through-holes 72 are formed in the cured reinforcing material 70 so as to expose the ground wiring 60 and the hot wiring 65. For example, an epoxy resin, a silicone resin, a polyimide resin, or an acrylic acid ester resin is applied as the reinforcing material 70 so as to have a thickness on the cover 50 of 30 μm and form the through-holes 72 with a diameter of 100 μm. The through-holes 72 are formed by lithography when a photosensitive resin is used, and are formed by laser when a non-photosensitive resin is used.

Then, as shown in Fig. 4(j), the external electrodes 80 are formed, which are connected to the ground wiring 60 and the hot wiring 65 via the through-holes 72 while the protection resin 16 is formed on the bottom surface 15 of the piezoelectric substrate 12.

Specifically, as a sub-film of the external electrode, Ni with a

thickness of 300 nm and Au with a thickness of 100 nm are sequentially formed on portions of the ground wiring 60 and the hot wiring 65 exposed from the through-holes 72 by electroless plating. Instead of forming the sub-film, the external electrodes themselves may also be electroless-plated with Ni and Au by embedding the through-holes 72 by electrolytic Cu plating. Then, after the entire wafer bottom surface of the piezoelectric substrate 12 is coated with an epoxy resin with a thickness of 10 μm, beaded external terminals are formed by printing the solder for external electrodes on portions of the through-holes 72 and by reflow-soldering thereon.

Finally, by dicing the wafer of the piezoelectric substrate 12 at the boundary between the surface-acoustic-wave filters 10a adjacent to each other, the piezoelectric substrate 12 is divided into each piece of the surface-acoustic-wave filter 10a. At this time, by cutting the reinforcing material 70, the supporting layer 30 and the cover 50 are prevented from being exposed due to the dicing.

When the groove 54 is formed on the cover 50, the short lines 25a to 25d (see Fig. 2) are removed and the wirings of the short lines 25a to 25d are not exposed outside the reinforcing material 70, improving the reliability of the surface-acoustic-wave filter 10a.

In addition, the surface-acoustic-wave filter 10a according to the second embodiment also has the same advantages as those of the surface-acoustic-wave filter 10 according to the first embodiment.

As described above, by sealing the vibratory space 26 around the IDT 22 with the reinforcing material 70, the surface-acoustic-wave filters 10 and 10a are improved in moisture resistance while being miniaturized, which need not be sealed after being mounted on a circuit board.

In addition, the present invention is not limited to the embodiments described above, so that various modifications can be made.

The present invention is not limited to the surface-acoustic-wave

filter, so that piezoelectric devices having elements using surface acoustic waves and piezoelectric devices, such as a bulk surface-acoustic-wave filter with a substrate having piezoelectric elements formed thereon using piezoelectric thin films, may also incorporate the invention.